Calculating Land Values by Using Advanced Statistical Approaches in Pendik

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Key words: Land valuation, value estimation, advance statistics, fuzzy logic, random forest

SUMMARY

In sustainable land development concept, primary factor is to obtain reliable and accurate information about land and to manage all this information efficiently. Definitive and reliable information about land and real property promote the geographical enablement and efficient information management which leads to achieve a sustainable development. In addition, governments need reliable value information of the land and real property for implementing many legal practices such as taxation, expropriation, market capitalization, rural-urban transformation and land consolidation. In Turkey, especially with the recent intensively performed urban transformation applications real estate valuation has increased its importance within the sector. Therefore, objective, accurate and reliable estimation of the value of land and real property has vital importance for real estate stakeholders. For this purpose, a variety of valuation techniques has been suggested in the literature, but there is no specific and widely-accepted method for estimating reliable and accurate land value. Classical valuation methods such as sales comparison, cost, income and regression have become sufficient in collective and objective land and property valuation processes. Land valuation consist of a multi-step and complex processes that input parameters are highly correlated and effective on accuracy. In order to overcome this problem, some non-parametric techniques including random forest and fuzzy logic have been recently used for land valuation purposes. In this study, parcel based valuation process for Pendik will be performed by using fuzzy logic and random forest algorithms. Firstly, criteria or parameters affecting the land value were determined according to the literature review. Secondly, ground truth dataset including a number of parcels having up-to-date market value was formed and training and validation samples were selected by applying stratified random sampling strategy in GIS environment. The prediction models of fuzzy logic and random forest were applied to whole dataset to produce land value map of the study area. Resulting maps and performance of the algorithms were compared and analysed in detail. All in all, fuzzy logic and random forest algorithms were found to be effective techniques for producing reliable and accurate land value maps.

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1. INTRODUCTION

The needs of societies in sustainable land development manner are reliable geographical data and information about their land, water and other under and over ground resources. Effective land administration, land management and land governance with comprehensive land policies helps to promote sustainable land development in both urban and rural areas (FIG, 2002). Reliable and definitive land administration infrastructures encourage spatial enablement and effective management of land (UNECE, 1996; Williamson, 2005). The availability of a comprehensive infrastructure for both the legal and thematic aspects of land administration will promote meeting social requirements from both the government and citizen perspectives (FIG, 2004; Marwick et al., 2012; Williamson et al., 2010; Rajabifard et al., 2013). Key factors for accomplishing successful and comprehensive land administration is ensuring reliable and extensive information about the tenure, value, and use of the land.

Land valuation has always been an important issue for societies and governments not only for achieving a sustainable land administration but also for successful implementation of expropriation, land consolation, urban-rural transformation and taxation applications. Moreover, in Turkey due to the intensively performed urban transformation applications, the importance and necessity of land valuation has been increased within the sector. There are many methods and approaches used in valuation process, but no certain and objective one exists (Nisanci, 2005). The most well-known and used valuation methods are sales comparison, cost and income methods (Aclar and Cagdas, 2008; Yalpir, 2007; Candas, 2012). In addition, the developing statistical approaches can be a good tool for obtaining better results with the analysis ability of Geographic Information Systems (GIS) (Yomralioglu, 1993; Zeng and Zhou, 2001; Pagourtzi et al., 2003; Derinpinar, 2014).

Sales comparison method is based on comparing a property to other properties with similar characteristics that have been sold recently. This method is very effective and helpful for determining the value of single-family detached homes (Dale and McLaughlin, 1988). In the cost method, value is determined by adding the estimated value of the land to the construction cost with all reproduction (how much a property would cost to replace) costs for improvements after subtracting accrued depreciation (The Appraisal of Real Estate, 2001). This method is useful especially for the valuation of new or nearly new properties (Candas, 2012). Income method is generally used when a property's use would generate a future income (Aclar and Cagdas, 2008). The value is estimated by taking the net income of the property and dividing it by the capitalization rate (The Appraisal of Real Estate, 2001). This method is more suitable for the evaluation of structured parcels and buildings such as apartments, working places and commercial buildings, which can provide rental income (Candas, 2012).

The parameters affecting land and real property are quite complex, and dependent on various parameters. In addition, sales values of them are statistical data due to their characteristics. Therefore, it can be more effective to use advance statistical approaches in land evaluation process (Yomralioglu, 1993; Nisanci, 2005). According to the literature review statistical approaches such as multiple regression, artificial neural networks, decision trees, support vector machines and fuzzy logic have been used for land and real property evaluations in many studies (Pagourtzi et al., 2003; Hansen, 2003; Gonzalez and Formosso, 2006; Bogataj et al., 2011; Kontrimas and Verikas, 2011; Bulut Nas 2011; Bozic et al., 2013; Gunes and Yildiz, 2015; Sarip and Hafez, 2015; Demetriou, 2016). In addition, the analysis capabilities of GISs can help to improve the understanding and efficiency of land and real property evaluation processes (McCluskey et al., 1997).

In this study, firstly advanced statistical techniques used for land valuation in this were explained in detail. Then, parameters affecting the land value were analysed and determined according to the literature review. After the determination of the parameters, parcel-based valuation process for Pendik was performed by using fuzzy logic and random forest algorithms with the help of GIS analysing tools. Finally, resulting maps and performance of the algorithms were compared and analysed in detail for both methods.

2. ADVANCED STATISTICAL TECHNIQUES FOR LAND VALUATION

A wide variety of different parameters are affecting the property value and it makes objective evaluations quite difficult. Therefore, in order to perform objective and accurate evaluations, all parameters related to land and property should be considered and taken into consideration (Yomralioglu and Nisanci, 2004). However, because there is no certain formula or approach for an impeccable evaluation, it is hard to say that there is an absolute objective valuation (Nisanci, 2005; Bulut Nas, 2011). In this point of view, it can be said that for achieving better evaluation results, advance statistical approaches may be performed (Yomralioglu, 1993; Nisanci, 2005). Because information alone is not enough for decision making, it should be analysed and interpreted logically and statistically for obtaining better results. In addition, the sales values are statistical and they should be statistically evaluated, corrected and interpreted (Candas, 2012). Statistical valuation is based on the principle to create a mathematical model with numerical or proportional relations between value and parameters that effect the value (Candas, 2012; Nisanci, 2005).

2.1 Determining Factors and Preparing Factor Data Sets

According to the literature study including academic researches, nationally and internationally accepted standard documents (CMB, 2006; TDUB, 2011; IVSC, 2011, TKGM, 2011; RICS, 2014; TEGoVA, 2016; Yomralioglu 1993; Nisanci, 2005; Candas 2012; Yalpir and Bunyan

Unel, 2016) factors that significantly affects the value of the real estate are determined. Determined factors and their short explanations were given in the Table 1.

Table 1. Factors Effecting Real Estate Value

Value Factor	Explanation
Distance to Public Services	This factor expresses the importantance of administrative and official buildings for property valuation process.
Distance to Educational Facilities	Educational facilities like kindergarten, primary education, secondary education, high school and university effect the value of the property.
Distance to Health Services	The presence and proximity of health services like family health centers, polyclinics, hospitals effect the value of the property.
Distance to Religious Centers	Although having a lower effect, proximity of the religious centers to the property affects its value positively.
Distance to Cultural Centers	Presence of the cultural centers such as theaters, cinemas and libraries at the location where the property is located effect the value of the property positively.
Distance to Shopping Centers	Big shopping malls provides a lot of services about food, entertainment and shopping which make them important attraction centers for property.
Exit to the Main Roads	Closeness to the main roads increases the value of the property.
Distance to the Main Roads	The proximity to the main roads and motorways affected the value positively.
Distance to Bus Stations	The distance to the bus stations is an important element for property and it increases the value.
Distance to Metro and Tram Stations	The proximity of the property to the metro and tram stations affects the value positively.
Distance to the Green Areas	The presence and closeness of green areas such as parks, playgrounds, picnic areas etc. affects the value positively.
Parking Area	The proximity of the property to parking areas affects the value positively.
Distance to the Airport	Closeness to airway transportation is considerably influential on the property value.
Distance to Industrial Areas	The proximity to industrial and production areas affects the value negatively.
Distance to Cemeteries	The closeness to the cemetery areas generally effect the value negatively.
Distance to Infrastructure Facilities	Infrastructure facilities such as treatment facility, transformers, power transmission stations etc. have a negative effect on the value.
Slope	Slope characteristics of the land are very important for proper settlement and effects the property value.
Aspect	Because Turkey is located in the north pole properties in the south are more valuable.

Population Density	Very dense and very low population has a negative effect on the property value.
Education Level	According to the literature research, it is determined that education and culture levels of the people living in the environment where the property is located are affecting the value in the socio-cultural sense.

Pendik province of Istanbul was chosen for the case study. Pendik is the neighbor to Tuzla in the east, Kartal and Sultanbeyli in the west, Şile in the north and Marmara Sea in the south (Figure 1). It has 7.5 km of coastline and 190 km² of surface area. Pendik is chosen is the case study area because of its large surface area and having urban-rural differences.

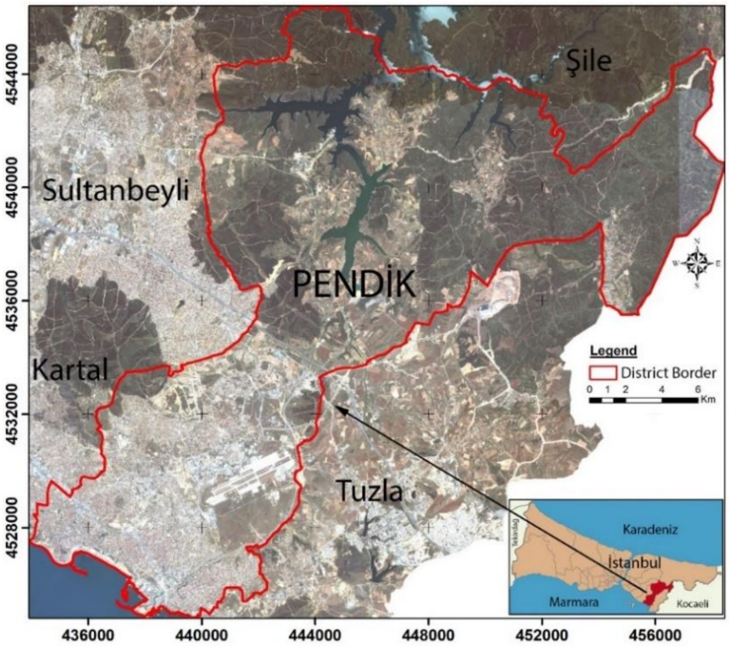

Figure 1. Study Area

Database having these criteria were produced in GIS environment for Pendik. Obtained geographic data sets were optimized with the help of the geographical analysis tools in ArcGIS software. The process steps are as follows:

<u>Data Harmonization</u>: Firstly, all data sets were converted into the ITRF 96 which is the designated coordinate system for merging all datasets into the same coordinate system. Available data are combined in the Pendik valuation database created for the case study application.

<u>Data Analysis Techniques</u>: Optimization should be done for the successful analysis and process of the existing data. Raster surfaces should be produced which express the geographical

characteristics of the study area. Analysis processes were performed in ArcGIS software environment.

For example, thematic distances of the administrative, educational, health, cultural facilities (Figure 2) were produced by using Euclidean distance analysis. Moreover, other thematic distances were produced by using Euclidean distance analysis for other thematic data; religion, cemetery, infrastructure, shopping facilities, airport, parking, industry and green areas, bus and metro stops, distances to streets and main roads. Thematic surfaces represented population density and education level were produced by using Kernel density analysis; slope and aspect characteristics were calculated by using slope and aspect analysis in ArcGIS software.

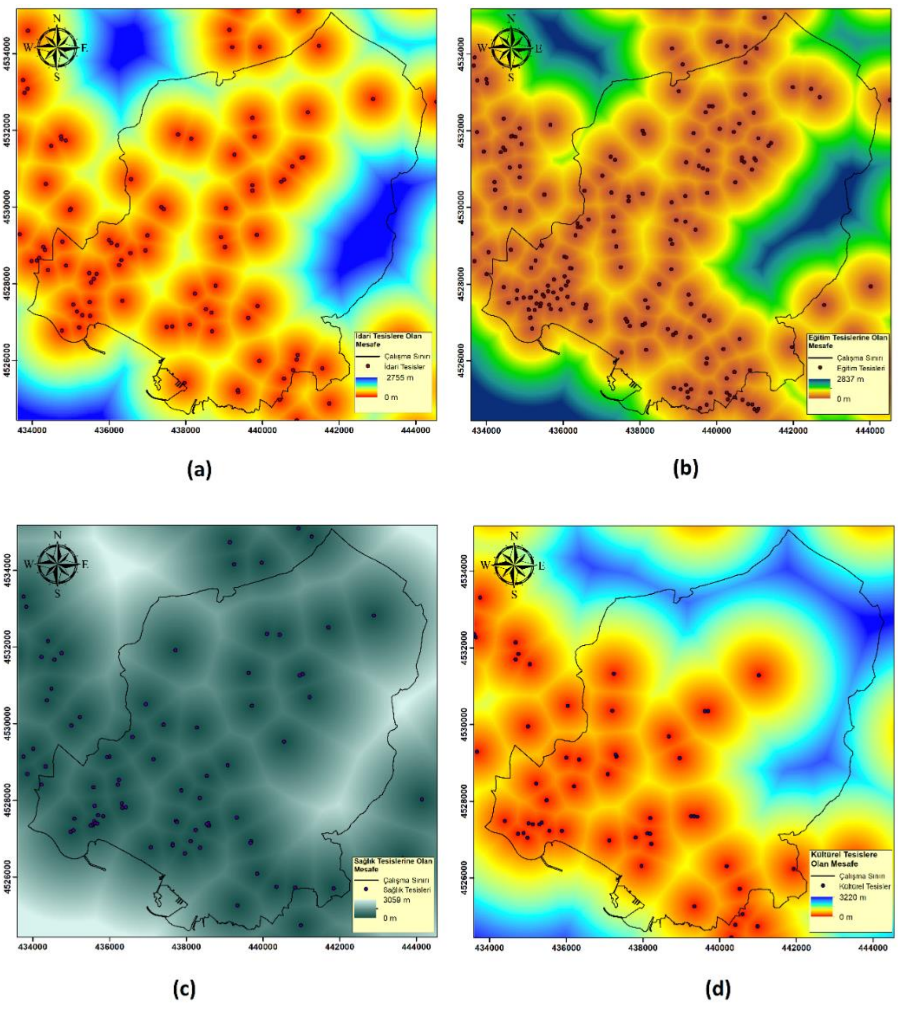

Figure 2. Thematic distance surfaces of Administrative (a), Education (b), Health (c), Cultural (d) for study area

2.2 Determining the Factor Impact Values by using Fuzzy Logic Approach

The factors affecting the real estate value are highly complex and depending on various parameters. Because information can be the form of verbal expressions such as large, small and little in fuzzy logic, it is an effective method for processing oral variables, which is very important for valuation process (Nedeljkovic, 2006; Yalpir and Ozkan, 2008). In fuzzy logic each element gets a value between 0 and 1, not just 0 or 1 (Zadeh, 1965). An element of a fuzzy set can be full member (100% membership) or a partial member (between 0% and 100% membership) (Nedeljkovic, 2006). That means an assigned membership value of an element is not restricted with two values, but can be 0, 1 or any value in-between.

According to Zadeh (1965), a fuzzy set is mathematically defined as Eq. 1; If X={x} denotes a space of objects, then the fuzzy subset A in X is a set of ordered pairs;

$$A = \{x, \mu A(x)\},\ x \in X \tag{1}$$

where the membership function µA(x) is known as the "degree of membership (d.o.m.) of x in A". Usually, µA(x) is a real number in the range [0, 1], where 0 indicates no-membership and 1 indicates full membership. The shape of the membership function varies according to the application area requirements. Various types of fuzzy membership functions have been defined in Figure 3.

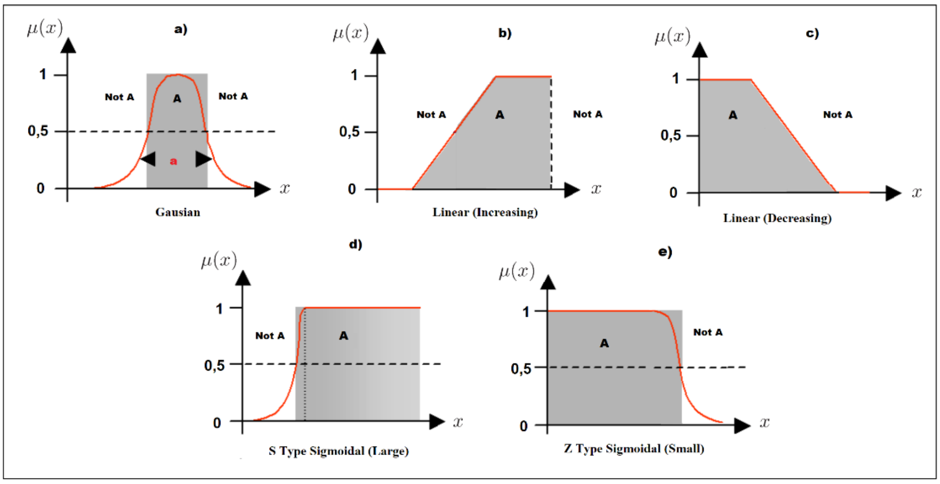

Figure 3. Used fuzzy membership functions

In Figure 3a) represents the Gausian Membership which is built on the Gaussian distribution curve and specifies the spread. Figure 3b) and c) represent the Linear Memberships in which minimum and maximum values are fixed at 0 and 1. Figure 3d) and e) represent Sigmoidal Memberships which are formed by the median value and the spread amount. 3d) represents the S type (Large) increasing sigmoid function where 3e) represents the Z type (Small) decreasing sigmoid function. Evaluations of the fuzzy rules are performed by using fuzzy set operations.

Within the application firstly, thematic surfaces surface produced in Section 2.1 were gathered in seven thematic groups according to their characteristics as public services, transportation, planning, socio-cultural factors, utilization, environmental factors and cultural factors. After groups were created, fuzzy membership functions were defined and applied for each thematic raster surfaces according to the characteristics of the data sets. In this way, each pixel in the raster data receives different pixel values ranging from 0 to 1. Then, fuzzy overlay maps were created for each thematic group by using fuzzy AND and OR functions in GIS. As an example, thematic surface representing the public service characteristics were created by using distance surfaces of educational, religious, healthcare and public facilities. Firstly, fuzzy memberships were determined according to the characteristics of each data. Then ideal accessibility distances and impacts were determined in order to apply fuzzy membership functions. For educational, religious and public facilities 800 m; for healthcare facilities 500 m were determined as ideal distances considering the literature studies. Finally, fuzzy surfaces were overlaid also by using fuzzy logic and thematic surface representing the public service characteristics was created (Figure 4).

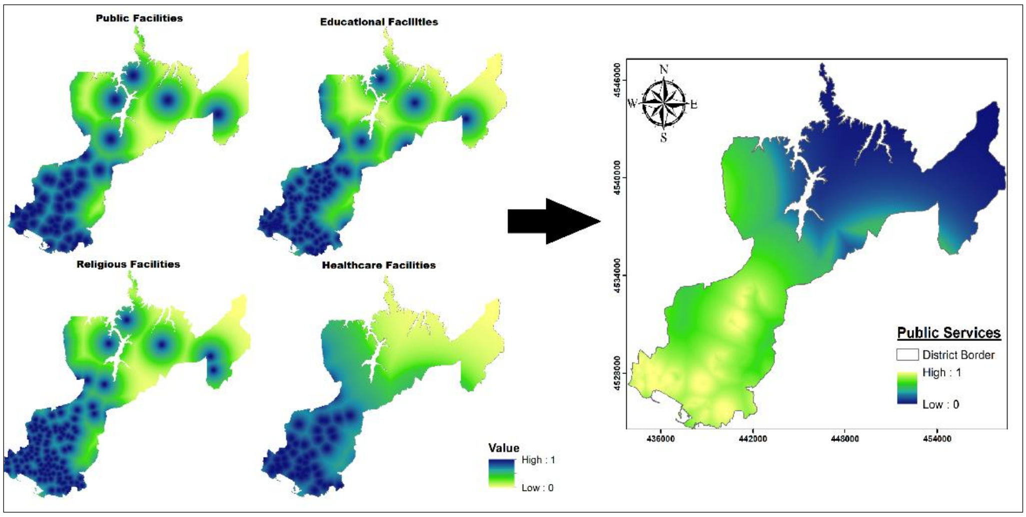

Figure 4. Creation of the Fuzzy Surface of Public Services

Same procedure was performed for other thematic groups (environmental factors, transportation, cultural factors, utilization, planning and socio-cultural factors) and fuzzy surfaces that demonstrate thematic impact values were created for each group (Figure 5).

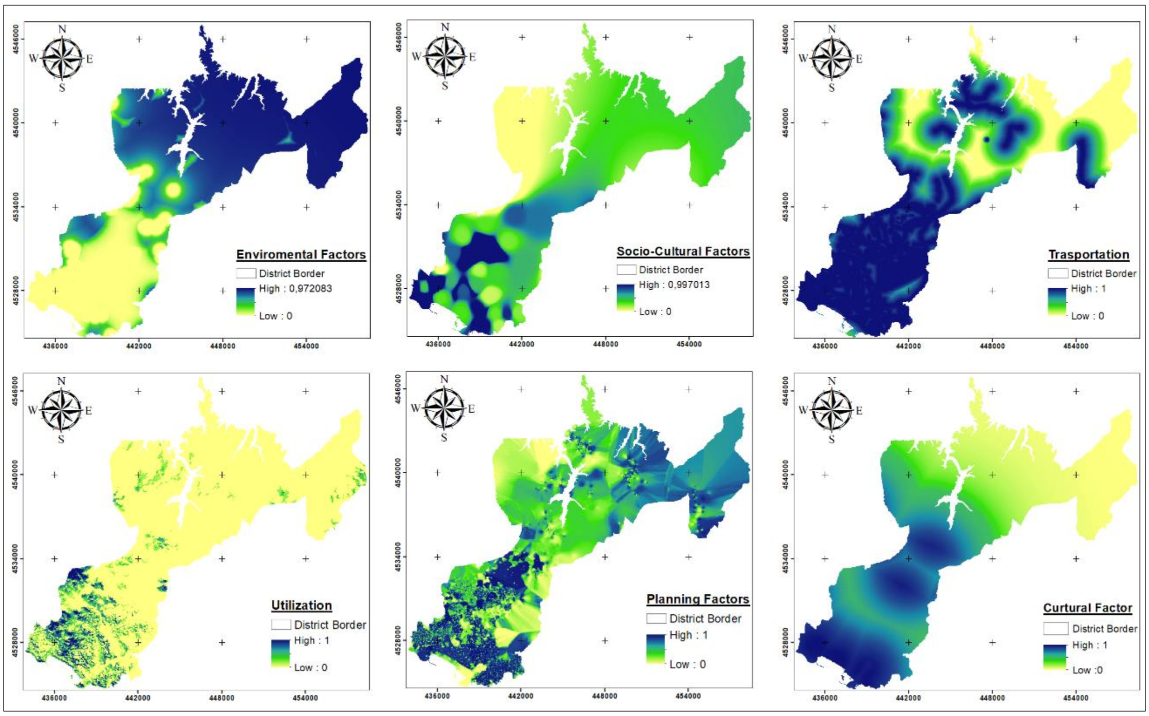

Figure 5. Creation of the Fuzzy Surfaces of Thematic Groups

2.3 Determining the Factor Impact Values by using Random Forest Algorithm

Random forest (RF) is one of the popular machine learning algorithms applied for various classification and regression problems. RF, widely known as tree based ensemble learning algorithm, is based on the idea that training a set of decision tree (DT) learners, using randomly selected samples through bootstrap aggregating (Bagging) strategy to make final a prediction (Breiman, 2001). About two thirds of the selected samples known as in-bag samples are used for training of each individual DT in the forest with the remaining one third known as out-of-bag samples are used in an internal cross-validation to estimate the predictive accuracy. By means of a majority vote, the results of the individual DT in the forest are combined and the model output is formed (Colkesen and Kavzoglu, 2017). For the implementation of RF algorithm, two parameters (the number of trees and the number of variables) have to be set by the analyst. In order to construct a RF prediction model, two randomization processes are employed. First, training samples for each individual tree are randomly selected by applying bootstrap sampling strategy. Second, rather than choosing the best split among all attributes, the tree inducer randomly samples a subset of the attributes and chooses the best one (Rokach, 2016). For this reason, RF can be viewed as an enhanced or generalized version of the bagging method that builds a randomized decision tree at each iteration.

Since the RF algorithm is a supervised learning algorithm, having a ground-truth data including up-to-date market value of the real estate is prerequisite for the construction of prediction model. For this purpose, up-to-date market valuee for 1.789 real-estate located in Pendik district of Istanbul province were determined as ground-truth data. Then, the ground-truth dataset was randomly split into 70:30 ratio for construction (training) and validation of the model respectively to evaluate the prediction performance of RF algorithm. As a result, 1.250 points were selected as a training set and 537 points were selected as a validation set.

For the application of RF, the number of trees (n) and the number of input variables considered in each node split (k) are to be set by the user-side. The input data set consisted of 21 factors, hence the number of input variables (m) was set to be 5 (i.e. $k = \sqrt{m}$ variables at each split). On the other hand, out-of-bag (OOB) error results of RF ensemble model was used to determine the number of trees parameter. For this purpose, input data set was firstly classified using a large number of trees (i.e. 500 trees) to estimate changes in OOB error with increasing number of trees. The resulting graph showing the relations between OOB error and the number of trees (n) was given in Figure 6. It was observed that there was a sharp decline in OOB error from 0.040 to less than 0.030 as number of tree increased from 1 to 150. After that, OOB error continued to decrease slightly until the number of trees takes value 250. From this critical point to larger tree sizes, OOB error stays stable. For this reason, the number of trees (n) was set to be 250 for the current study. The predictive accuracy of RF model constructed with the user-defined parameters was tested using root-mean-square error (RMSE), mean-absolute-error (MAE) and correlation coefficient (CorC) statistics, estimated as 0.103, 0.0758 and 0.799 respectively.

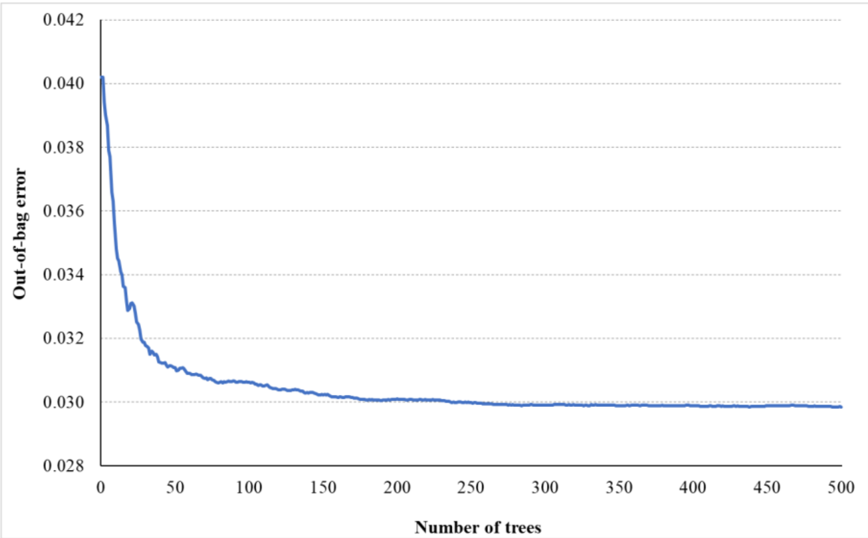

Figure 6. Out-of-bag (OOB) error graph for random forest estimation

The RF model constructed with optimal parameter setting applied to whole dataset to produce land valuation map of the study area. The resulting thematic map was given in Figure 7. When the produced thematic map was analysed, it was observed that the south-west part of the Pendik district especially the lands situated along the sea side were predicted as high land value. Furthermore, areas close to the shopping centre located to the north-east part of the study area were also predicted as zones with high value.

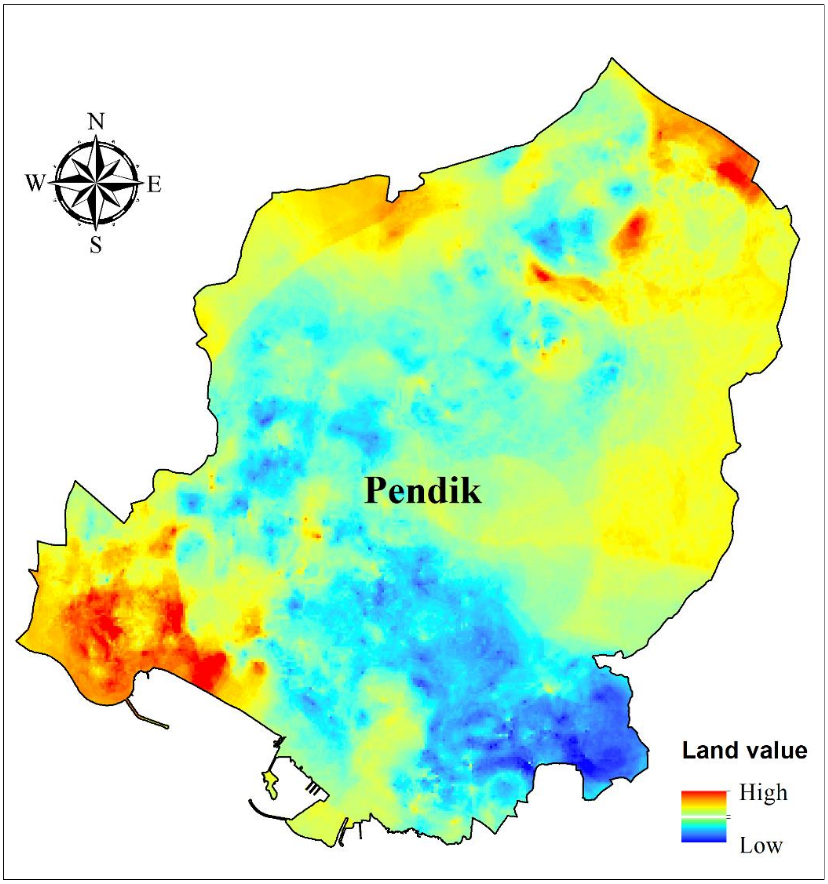

Figure 7. Land value map of the study area produced by RF algorithm.

CONCLUSION

Determination of the reliable, objective and accurate value of the real estate is quite difficult and requires expertise in technical and legal aspects. Physical, locational, legal and economical characteristics of the real estate should be taken into consideration. Therefore, selection of the appropriate method and all thematic and legal factors affecting the real estate is quite important for better estimations. Classical methods are not suitable for mass and automated valuation process. Recently developed computer and information technologies provide important advantages to real estate valuation. GIS and its spatial analysis capabilities with decision support technologies make effective and reliable valuation process possible.

In this study, usability and effectivity of the fuzzy logic and random forest algorithm in real estate valuation were tested and analysed. After the determination of the criteria affecting the value according to the literature review, a case study in Pendik was performed. Fuzzy logic approach was performed to predict the value trends of thematic factor groups. Each criterion in the application area was analysed and gathered in seven thematic groups with the help of GIS spatial analysis tools. In this way, thematic value trends for the application area were determined with unsupervised learning approach. For overall value prediction, random forest algorithm was performed by using 1.789 sample data (70:30 training/validation ratio) about Pendik with supervised learning approach. In this way, thematic map representing value range of the application area was produced with 0.103 RMSE, 0.0758 MAE and 0.799 CorC.

The resulting thematic map produced with RF algorithm demonstrates the model predictions in the south-west part of the Pendik, while thematic maps produced with fuzzy logic approach demonstrate value trends in each thematic factor group. When the model predictions were analysed, sea side part were predicted as high value, confirming the result produced by fuzzy logic algorithm. Furthermore, areas close to the shopping centre located to the north-east part of the study area were also predicted as zones with high value. According to the results, it can be said that fuzzy logic and random forest algorithms with the help of GIS analysis capabilities gives successful results and can be used for mass real estate valuation.

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